Helicity-dependent extension of the McLerran-Venugopalan model

F. Cougoulic (JYU), Y. V. Kovchegov (OSU).

DIS 2021 - April 12-16, 2021.

- **Proton spin puzzle**: since 1988 and EMC mesurement of g_1^γ [PLB 206, 2 (1988)]
  $\rightarrow$ Missing spin in terms of QCD dof.
- Jaffe Manohar decomposition [Nucl. Phys. B337, 509 (1990)]:

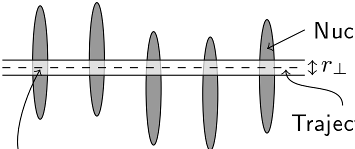
$$\frac{1}{2} = \frac{1}{2}\Sigma_q + \Sigma_g + L_q + L_g$$

Quark OAM (L_q), Gluon OAM (L_g), Gluon spin (Σ_g), Quark spin (Σ_q), Proton spin ($\frac{1}{2}$)

- Consider $\Sigma_q = \int_0^1 \mathrm{d}x \left(q^\uparrow(x) - q^\downarrow(x)\right)$. $\Rightarrow$ Experiments: finite range of $x \in [x_{min}, x_{max}]$.
- Theory: our only hope for the region of $x \in [0, x_{min}]$. $\Rightarrow$ Small-x framework.

- For helicity-dependent operator: Require beyond JIMWLK evolution.
  $\rightarrow$ Use h-JIMWLK kernel [PRD 100 (2019) 11, 114020].
- Solving h-JIMWLK evolution require an initial condition:
  $\Rightarrow$ **Helicity-dependent extension of the MV-model**.

Assumptions and two points correlation functions.



Assumptions

- Uncorrelated nucleons
- Each nucleon is dilute ($N_p \ll n$):
$$P(k \ll N_p) \sim \frac{1}{k!}\left(\frac{N_p}{n}\right)^k$$
- Large nucleus $A \gg 1$
- pQCD region:
$$\Lambda^2_{QCD} \ll 1/r^2_\perp \ll \mu^2 \propto A^{1/3}$$

Correlation functions (For simplicity, each nucleon is made of $\sum_\sigma N^\sigma_q$ quarks)

$$\langle A|j^a_\sigma(\underline{x}, x^-)\, j^b_{\sigma'}(\underline{y}, y^-)|A\rangle = \delta^{ab}\,\delta_{\sigma\sigma'}\,\mu^2_\sigma(\underline{x}, x^-) \times \delta(x^- - y^-)\,\delta^2(\underline{x} - \underline{y}), \tag{1}$$

$$\mu^2_\sigma(\underline{x}, x^-) = 2\pi\alpha_s \frac{N^\sigma_q}{N_c}\,\rho_A(\underline{x}, x^-). \tag{2}$$

$$\langle A|J^{i\,\sigma}_\psi(\underline{x}, x^-)\, J^{j\,\sigma'}_{\bar\psi}(\underline{y}, y^-)|A\rangle = -\delta^{ij}\,\delta_{\sigma\sigma'}\,\frac{\nu^2_{(-\sigma)}(\underline{x}, x^-)}{\sqrt{2}\,\langle p^+\rangle} \times \delta(x^- - y^-)\,\delta^2(\underline{x} - \underline{y}), \tag{3}$$

$$\nu^2_\sigma(\underline{x}, x^-) = 4\pi\alpha_s \frac{C_F\, N^\sigma_q}{N_c}\,\rho_A(\underline{x}, x^-). \tag{4}$$

ρ_A = Nucleon density, N^σ_q = Number of quarks with helicity σ in each nucleon.

Main Result: [NPA 1004 (2020) 122051]

$$\mathcal{W}^{(0)}[\alpha,\beta,\psi,\bar\psi] \propto \exp\left\{\int \mathrm{d}^2x_\perp dx^- \, \langle p^+\rangle \left[\frac{\nu_+^2+\nu_-^2}{\nu_+^2\,\nu_-^2}\,\bar\psi\tfrac{1}{2}\gamma^+\nabla_\perp^2\psi - \frac{\nu_+^2-\nu_-^2}{\nu_+^2\,\nu_-^2}\,\bar\psi\tfrac{1}{2}\gamma^+\gamma^5\nabla_\perp^2\psi\right]\right\}$$

$$\times\exp\left\{-\int \mathrm{d}^2x_\perp dx^- \; \mathrm{tr}\left[(\nabla_\perp^2\alpha)^2\,\frac{\mu_+^2+\mu_-^2}{8\mu_+^2\,\mu_-^2} + \left(\langle p^+\rangle\beta\right)^2\frac{\mu_+^2+\mu_-^2}{2\mu_+^2\,\mu_-^2} + (\nabla_\perp^2\alpha)\langle p^+\rangle\beta\frac{\mu_+^2-\mu_-^2}{2\mu_+^2\,\mu_-^2}\right]\right\}$$

Where we used the EOM to relate sources $\{j_\sigma, J_\psi, J_{\bar\psi}\}$ to fields $\{\alpha,\beta,\psi,\bar\psi\}$:

$$j_\sigma = -\tfrac{1}{2}\nabla_\perp^2\alpha \;+\; \sigma\langle p^+\rangle\beta \tag{5}$$

$$J_\psi^\sigma = \chi_\sigma^T\, j_\psi = \chi_\sigma^T\,[i\partial\!\!\!/ - m]\psi \tag{6}$$

Prospect

- Stochastic formulation of the h-JIMWLK equation, using the h-MV model as an initial condition.
  This should allow numerical evaluation at all N_c and N_f of any helicity dependent operator at small-x.